# Use of DPOSS data to study globular cluster halos: an application to M 92

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Abstract. We exploited the large areal coverage offered by the Digitized Palomar Observatory Sky Survey to analyze the outermost regions of the galactic globular cluster M 92 (NGC 6341). Two independent photometric reduction programs (SKICAT and DAOPHOT) were used to construct a color-magnitude diagram and a surface density profile for this cluster, based on Jand F-band DPOSS plates. A strong similarity has been found in the performance of the two programs in the low-crowded outermost cluster regions. After removing the background contribution, we obtained the cluster outer surface density profile down to a surface brightness magnitude of  $\mu_V \sim 31 \text{ mag arcsec}^{-2}$ and matched it with the inner profile of Trager et al. (1995). The profile shapes match very well: since our data are uncalibrated, the shift in magnitudes between the profiles has been also used to calibrate our profile. The analysis shows that the cluster has an extra tidal halo extending out to  $\sim 30'$  from the cluster center at a 3  $\sigma$  level over the background noise. This halo is revealed to be almost circular.

**Key words:** Galaxy: globular clusters: general – Galaxy: kinematics and dynamics – Galaxy: globular clusters: individual: M 92

# 1. Introduction

The tidal radii of globular clusters (GCs) are important tools for understanding the complex interactions of GCs with the Galaxy. In fact, they have traditionally been used to study the mass distribution of the galactic halo (Innanen et al. 1983), or to deduce GCs orbital parameters (Freeman & Norris 1981; Djorgovski et al. 1996). Tidal radii have usually been *estimated* (only in few cases *directly* measured), by fitting King models to cluster density profiles rarely measured from the inner regions out to the tidal radius, because of the nature of the photographic material, that prevented any measure in the cluster center, and the small format of the first digital cameras. Only in the last few years, the advent of deep digitized sky surveys and wide field digital detectors has allowed us to deal with the overwhelming problem of contamination from field stars and to probe the outer region of GCs directly (Grillmair et al. 1995, hereafter G95; Zaggia et al. 1995; Zaggia et al. 1997; Lehman & Scholz 1997). The study of tidal tails in galactic satellites is gaining interest for many applications related to the derivation of the galactic structure and potential, the formation and evolution of the galactic halo, as well as the dynamical evolution of the clusters themselves. Recent determinations of proper motion for some globular clusters with HIPPARCOS have made it possible to estimate the orbital parameters of a good number of them (Dinescu et al. 1999). This helps to clarify the nature and structure of tidal extensions in GCs.

In principle, available tools to enhance cluster star counts against field stars rely on the color-magnitude diagram (CMD), proper motions, radial velocities, or a combination of the three techniques. The application of these techniques to GCs have led to the discovery that tidal or extra-tidal material is a common feature: Grillmair (1998), for instance, reported the discovery of tidal tails in 16 out of 21 globular clusters. Interestingly, signature of the presence of tidal tails in GCs has also been found in four GC's in M31 (Grillmair et al., 1996). For galactic clusters, the discovery was made by using a selection in the CMD of cluster stars on catalogs extracted from digitized photographic datasets. The CMD selection technique is an economical and powerful method to detect GC tails, since it significantly decreases the number of background and/or foreground objects.

In order to test the feasibility of a survey of most GCs present in the Northern hemisphere, we applied the CMD technique to the galactic globular cluster M 92 (NGC 6341), with the aim of measuring the tidal radius and searching for the possible presence of extra-tidal material. We used plates from the Digitized Second Palomar Sky Survey (hereafter DPOSS), in the framework of the CRoNaRio (Caltech-Roma-Napoli-Rio de Janeiro) collaboration (Djorgovski et al. 1997; Andreon et al. 1997; Djorgovski et al. 1999). A previous account on this work was given in Zaggia et al. (1998). This is the first of a series of papers dedicated to the subject –an ideal application for this kind of all-sky surveys.

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Fig. 1. A comparison of objects detected in the inner parts of M 92 by SKICAT (filled triangles) and DAOPHOT (dots) for the two different plates: J (upper panel) and F (lower panel). The inner circle (continuous) marks the circular aperture where plate detections cannot be used. The outer circle (short-dash) marks the annular region where crowding correction is important. In both panels North is up and East is to the right. The two diagonal bands in the lower panel indicate the satellite

### 2. The color-magnitude diagram

The material used in this work are the J and F DPOSS plates of the field 278. For each band, we extracted from the whole digitized plate a sub-image (size:  $8032 \times 8032$  pixels), corresponding to an area of  $136' \times 136'$ , with a pixel size of 1", centered on M 92 at coordinates (Harris 1996):

 $\alpha_{J2000} = 17^h \ 17^m \ 07.3^s$  $\delta_{J2000} = +43^o \ 08' \ 11.5''.$ 

The two images were linearized by using a density-tointensity (DtoI) calibration curve, provided by the sensitometric spots available on the DPOSS plates. The F plate is contaminated by two very similar satellite tracks (as an alternative, the two tracks come from a high altitude civil airplane) lying  $\sim 9'$  and  $\sim 13'$  from the cluster center and crossing the field in a South-East/North-West direction. The effect of these tracks can be seen as empty strips on the lower panel of Fig. 1. Other thin, fainter tracks and some galaxies are present on the same plate, but at larger distances from the cluster core region. We applied the CMD technique to datasets obtained with different astronomical packages, in order to test the reliability of object detection and photometry in crowded stellar fields. On the DPOSS plates containing M 92, we used both the SKICAT and DAOPHOT packages. SKICAT, written at Caltech (see Weir et al. 1995a, and refs. therein), is the standard software used by the CRoNaRio collaboration for the DPOSS plate processing and catalog construction. DAOPHOT is a well-tested program for stellar photometry, developed by Stetson (1987), and widely used by stellar astronomers. In this work we have used DAOPHOT only to obtain aperture photometry, with APPHOT, of objects detected with the DAOFIND algorithm on the DPOSS plates.

## 2.1. The data set

The SKICAT output catalog only contains objects classified as stars in both filters. For each object, we used  $M_{\rm Core}$  (the magnitude computed from the central nine pixels), because the other aperture magnitude is measured on an area far too large for crowded regions. The final SKICAT catalog consists of 108779 objects. Since SKICAT is optimized for the detection of faint galaxies, in the present case we needed to test its performances in crowded stellar fields to ensure that it properly detected the stellar population around the cluster.

Thus, SKICAT has been compared to DAOPHOT, which is specifically designed for crowded fields stellar photometry and has been repeatedly tested in a variety of environments, including globular clusters. The DAOPHOT dataset was built using aperture photometry on the objects detected with the DAOFIND. The threshold was set at 3.5  $\sigma$ , similar to the one used by SKICAT. Aperture photometry was preferred to PSF fitting photometry, due to the large variability of the DPOSS point-spread function which makes the PSF photometry less accurate than the aperture photometry. We used an aperture of 1.69 pixels of radius, corresponding to an area of approximately 9 pixels, i.e. equivalent to the area used by FOCAS/SKICAT to compute  $M_{\text{Core}}$ . Indeed, the advantages of using PSF fitting are more evident in the central and more crowded regions of the cluster, while we are mainly interested in the outskirts, where crowding is less dramatic. Thus, we adopted the results from the aperture photometry, and we refer to this dataset as the DAOFIND+PHOT dataset.

The total number of objects detected in the J and F plates is, respectively, 240138 and 253977. The larger number of objects detected by DAOFIND, compared to those from SKICAT,

tracks where SKICAT detects no objects.





Fig. 2. Comparison between SKICAT  $M_{Core}$  and DAOPHOT aperture magnitude in the filters F (upper panel) and J (lower panel). The histograms of the distributions, expressed in percentage of the total, are reported at the right edge of the plots.

is mainly due to the better capacity of DAOFIND in detecting objects in the crowded regions of the core. In the case of DAOFIND, since the convolution kernel, which is set essentially by the pixel size and seeing value, is much smaller than in SKICAT, we also have objects measured near the satellite tracks.

The FOCAS/SKICAT and DAOFIND+PHOT aperture photometry were then compared, and the results are shown in Fig. 2 where the SKICAT aperture magnitude is plotted versus the difference between itself and  $M_{\rm Core}$ . The average difference is zero, with an error distribution typical of this kind of tests, i.e. a fan-like shape with growing dispersion at fainter magnitudes. The distribution of F magnitudes in Fig. 2 clearly shows the effects of saturation at the bright end, and in both plots there are several outliers, owing to the field crowding. In fact, these outliers are much more concentrated in the inner 12', where their density is  $0.439 \operatorname{arcmin}^{-2}$ , than at larger distances from the center, where the density drops to  $0.022 \text{ arcmin}^{-2}$ . These objects are mostly classified as non stellar by SKICAT and DAOPHOT, since they are either foreground galaxies or, more often, unresolved multiple objects, and were rejected in the final catalogs. Their area is taken into account later on, when we compute the effective area of the annuli in the construction of the radial profile. The outliers show an asymmetric distribution with SKICAT magnitudes being brighter at bright magnitudes and viceversa at fainter magnitudes. This is due to two reasons: in the case of large objects, SKICAT splits them into multiple entries, but keeps the  $M_{\rm Core}$  value of the originally detected (big) object; at fainter magnitudes, where objects are small,  $M_{\rm Core}$  is computed on a number of pixels less than 9, while the aperture photometry of the objects in the DAOFIND catalog are always computed on a circle of 1.69 pixel radius. However, the contribution of these outliers to the counts is far below 1 percent of the total, as can be seen from the histogram plotted on the right hand side of Fig. 2.

The above analysis shows that SKICAT catalogs are, after a suitable cleaning, usable "as they are" also for studies of moderately crowded stellar fields. We shall use the DPOSS-DAOPHOT dataset because it can better detect objects in highly crowded fields, which allows us to probe into the inner (200'' < r < 400'') regions of the cluster and merge our star counts profile with the published one of Trager et al. (1995, hereafter T95).

#### 2.2. The color-magnitude diagram

In order to build the CMD of the cluster, individual catalogs were matched by adopting a searching radius of 5 ", and keeping the matched object with the smallest distance. The derived CMD is shown in Fig. 3 for two annular regions: the inner one, between 5' and 12' from the center (left-hand panel) and the outer one, referring to the background, between 60' and 67' (right-hand panel). The M 92 turn-off region, as well as part of the horizontal branch, are clearly visible. At bright magnitudes, the giant branch turns to the blue, due to plate saturation. At large angular distances from the center of M 92, most objects are galactic stars with only a small contribution from the cluster.

For reducing the background/foreground field contribution, we used an approach similar to that of Grillmair et al. 1995. First of all, We selected an annular region (200'' < r < 300'')around the cluster center to find the best fiducial CMD sequence of the cluster stars. Then, the CMD of this region was compared with the CMD of the field at a distance greater than  $\simeq 1^{\circ}$  from the cluster center. The two CMD's were normalized by their area and then we binned the CMD and computed the S/N ratio of each element, just like in G95 (their Eq. 2). Finally, we then obtained the final contour of the best CMD region by cutting at a  $S/N \simeq 1$ . Contours are shown in Fig. 3, on which a solid line marks the CMD region used to select the "bona fide" cluster stars as described above. We must say that this CMD selection is not aimed at finding all the stars in the cluster but only at the best possible enhancement of the cluster stars as compared to the field stars. This is why the region of the sub-giant/giant branch is not included, since here the cluster stars are fewer than in the field. By extracting objects at any distance from the center of the cluster, in the selected CMD region, the field contamination is reduced by a factor of  $\sim 7$ . In absence of strong color gradients, the fraction of lost stars does not depend on the distance from the center.

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# 3. Extra-tidal excess in M 92

# 3.1. Radial density profile

As first step, we built a 2-D star density map by binning the catalog in step of  $1' \times 1'$ . Then, we fitted a polynomial surface to the background, selecting only the outermost regions of the studied area. The background correction is expressed in the same units of 2-D surface density counts, and can be directly applied to the raw counts. A tilted plane was sufficient to interpolate the background star counts (SCs). Higher-order polynomials did not provide any substantial improvement over the adopted solution. We compared the fitted background with IRAS maps at  $100\mu$ , but we did not find any direct signs of a correlation between the two. Rather, the direction of the tilt is consistent with the direction of the galactic center. Hence, the tilt of the background, which is however very small ( $\sim 0.01 \text{mag/arcmin}$ ), can be considered as due to the galactic gradient.

The cluster radial density profile was obtained from the background subtracted SC's by counting stars in annuli of equal logarithmic steps. The uncorrected surface density profile (hereafter SDP) is expressed as:

$$SDP_{i}^{\text{uncorr}} = -2.5 * log(N_{i,i+1}/A_{i,i+1}) + const,$$

where  $N_{i,i+1}$  indicates the number of objects in the annulus between  $r_i$  and  $r_{i+1}$ , and  $A_{i,i+1}$  the area of the annulus. The constant was determined by matching the profile with the published profile of T95 in the overlap range. The effective radius at each point of the profile is given by:

$$r_i^{\rm eff} = \sqrt{\frac{1}{2}} \times (r_i^2 + r_{i+1}^2).$$

The SDP must now be corrected for crowding. When dealing with photographic material, it is not possible to apply the widely known artificial star technique used with CCD data. Therefore,

**Fig. 3.** Color magnitude diagram of the stars detected in the field of the globular cluster M 92. *Left panel:* CMD of M 92 in an annular region at 5' < r < 12'. *Right panel:* background field CMD in an annulus at 60' < r < 67'.

we used a procedure similar to the ones described in Lehman & Scholz (1997) and Garilli et al. (1999): we estimated the area occupied by the objects in each radial annulus by selecting all the pixels brighter than the background noise level plus three sigmas, and considered as virtually uncrowded the external annuli in which the percentage (very small,  $\simeq 0.5\%$ ) of filled area did not vary with the distance. The external region starts at  $\sim 1000''$  from the cluster center with a filling factor smaller than  $\simeq 2\%$ . After correcting the area covered by non-stellar objects, the ratio unfilled/filled area gives the crowding correction. This correction was computed at the effective radii of the surface brightness profile (hereafter SBP) and smoothed using a spline function. The corrected surface brightness profile was then computed as:

$$SBP_i = SBP_i^{\text{uncorr}} + 2.5 \times \log(1.0 - frac)$$

where frac is the crowding correction factor determined at the i-th point on the profile.

The crowding corrected SBP of M 92 derived from DPOSS data is shown in Fig. 4 as filled dots and the uncorrected counts as crosses. Table 1 lists the measured surface brightness profile. With a simple number counts normalization we joined our profile to the one (open circles) derived by T95, in order to extend the profile to the inner regions. We then fitted a single-mass King model to our profile. The fitting profile is drawn on Fig. 4 as a continuous line. Our value for the tidal radius,  $r_t = 740''$ , turned out to be similar to the value given in Brosche et al. (1999),  $r_t = 802''$  and slightly smaller than the one given in T95,  $r_t = 912''$ . As it can be seen from the figure, DPOSS data extend at larger radial distances than the T95 compilation and reveal the existence of a noticeable deviation from the isotropic King model derived from the direct fitting of the SBP. This deviation is a clear sign of the presence of extra tidal material. We



**Fig. 4.** M 92 radial density profile. Open dots, Trager et al. (1995) data; filled dots, DPOSS SCs; crosses, crowding uncorrected SCs; solid line, isotropic King model.

	Table	1.	Measured	surface	brightness	profile
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$\log(r)$	$V_{SBP}^{uncorr.}$	$V_{SBP}^{corr.}$	$\sigma(V_{SBP})$
2.307	24.09	21.84	0.09
2.348	23.90	22.39	0.06
2.389	23.96	23.10	0.09
2.431	23.83	23.22	0.05
2.472	24.00	23.62	0.07
2.514	24.17	23.89	0.06
2.555	24.50	24.36	0.06
2.596	24.89	24.79	0.07
2.638	25.26	25.19	0.07
2.679	25.87	25.82	0.10
2.720	26.25	26.21	0.09
2.762	26.79	26.75	0.13
2.803	27.38	27.34	0.14
2.845	27.97	27.93	0.19
2.886	28.70	28.66	0.30
2.927	28.90	28.86	0.28
2.969	29.76	29.72	0.54
3.010	29.61	29.56	0.41
3.052	29.75	29.71	0.41
3.093	29.73	29.69	0.38
3.134	30.03	29.98	0.43
3.176	29.91	29.87	0.36
3.217	30.46	30.42	0.51
3.300	31.28	31.23	0.85
3.341	31.02	30.97	0.62
3.383	30.87	30.82	0.50
3.424	31.26	31.21	0.63
3.466	31.24	31.19	0.57

also tried fitting anisotropic King models to the SBP, but the fit was not as good as in the isotropic case.

At what level is this deviation significant? The determination of the tidal radius of a cluster is still a moot case. While fitting a King model to a cluster density profile, the determination of the



**Fig. 5.** Fit of a power law to the external profile of M 92, expressed in number surface density to allow for an immediate comparison with Johnston et al. (1999, hereafter J99), and binned to smooth out oscillations due to the small dimension of the annuli. Triangles indicate the profile of the extra-tidal halo. Diamonds represent the binned and averaged profile within the tidal radius. The dashed line is the fitting power law with  $\gamma = -0.85 \pm 0.08$ .

tidal radius comes from a procedure where the overall profile is considered, and internal points weigh more than external ones. On the one hand, this is an advantage since the population near the limiting radius is a mix of bound stars and stars on the verge of being stripped from the cluster by the Galaxy tidal potential. On the other hand, the tidal radius obtained in this way can be a poor approximation of the real one. In the classical picture, and in presence of negligible diffusion, the cluster is truncated at its tidal radius at perigalacticon (see Aguilar et al. 1988). Nevertheless, Lee & Ostriker (1987) pointed out that mass loss is not instantaneous at the tidal radius, and, for a given tidal field, they expect a globular cluster to be more populated than in the corresponding King model. Moreover, a globular cluster along its orbit also suffers from dynamical shocks, due to the crossing of the Galaxy disk and, in case of eccentric orbits, to close passages near the bulge, giving rise to enhanced mass-loss and, later on, to the destruction of the globular cluster itself. Gnedin & Ostriker (1997) found that, after a gravitational shock, the cluster expands as a whole, as a consequence of internal heating. In this case, some stars move beyond the tidal radius but are not necessarily lost, and are still gravitationally bound to the cluster. This could explain observed tidal radii larger than expected for orbits with a small value of the perigalacticon. Brosche et al. (1999) point out that the observed limiting radii are too large to be compatible with perigalacticon  $r_{\rm t}$ , and suggest that the appropriate quantity to be considered is a proper average of instantaneous tidal radii along the orbit. It can be seen from Fig. 4 that the cluster profile deviates from the superimposed King model before the estimated tidal radius, and has a break in the slope at about  $r \sim 850''$ , after which the slope is constant. We shall come back later to this point.

In Fig. 5 we show the surface density profile, expressed in number of stars to allow a direct comparison with J99, and binned in order to smooth out oscillations in the profile, due to the small S/N ratio arising with small-sized annuli. J99 predict that stars stripped from a cluster, and forming a tidal stream, show a density profile described by a power law with exponent  $\gamma = -1$ . We fitted a power law of the type  $\Sigma(r) \propto r^{\gamma}$  to the extra-tidal profile (dashed line). The best fit gives a value  $\gamma =$  $-0.85 \pm 0.08$  and is shown as a dashed line in Fig. 5. The errors on the profile points include also the background uncertainty, in quadrature, so that the significance of the extra-tidal profile has been estimated in terms of the difference  $f_i - 3\sigma_i$ , where  $f_i$  is the number surface density profile at point *i*, and  $\sigma_i$  its error, which includes the background and the signal Poissonian uncertainties. This quantity is positive for all the points except for the outermost one. The fitted slope is consistent with the value proposed by J99 and in good accordance with literature values for other clusters (see G95 and Zaggia et al. 1997).

We then fit an ellipse to the extra-tidal profile in order to derive a position angle of the tidal extension, and checked whether the profile in that direction differs from the one obtained along the minor axis of the fitting ellipse, to confirm that the extra-tidal material is a tail rather than a halo. The best fitting ellipse, made on the "isophote" at the  $2\sigma$  level from the background (approximately  $1.5r_t$  from the center of the cluster), turned out to have a very low ellipticity, ( $e \le 0.05 \pm 0.01$  at P.A. $\simeq 54^\circ \pm 15^\circ$ ). We have also measured the radial profiles along the major and minor axes, using an aperture angle of  $\pm 45^\circ$ , in order to enhance the S/N ratio in the counts. The two profiles turned out to be indistinguishable within our uncertainties. This result shows that the halo material has a significantly different shape than the internal part of the cluster which shows an ellipticity of  $0.10 \pm 0.01$  at P.A.  $141^\circ \pm 1$  as found by White & Shawl (1987).

#### 3.2. Surface density map

In the attempt to shed more light upon presence and characteristics of the extra-tidal extension, we used the 2-D star counts map, as described at the beginning of the previous section. We applied a Gaussian smoothing algorithm to the map, in order to enhance the low spatial frequencies and cut out the high frequency spatial variations, which contribute strongly to the noise. We smoothed the map using a Gaussian kernel of 6'. The resulting smoothed surface density map is shown in Fig. 6. Since the background absolute level is zero, the darkest gray levels indicate negative star counts. In this image, the probable tidal tail of M 92 (light-gray pixels around the cluster) is less prominent than in the radial density profile: this is because data are not averaged in azimuth. On the map we have drawn three "isophotal" contours at 1, 2 and 3  $\sigma$  over the background. The fitted tidal radius is marked as a thick circle and the two arrows point toward the galactic center (long one) and in the direction of the measured proper motion (see Dinescu et al. 1999). The tidal halo does not seem to have a preferred direction. A marginal sign of elongation is possibly visible along a direction almost orthogonal to that of the galactic center.

As pointed out in the previous section, if we build the profile along this direction and orthogonally to it, we do not derive clear



**Fig. 6.** M 92 surface density map from background subtracted star counts. The black, thick circle is drawn at the estimated tidal radius of M 92. The long, thicker arrow indicates the direction of the galactic center, the thin arrow indicates the proper motion of the cluster as in Dinescu et al. (1999). Contours are drawn at 1,2 and 3  $\sigma$  of the background.

signs of any difference in the star count profiles in one direction or the other, mainly because of the small number counts.

On the basis of these results, we can interpret the extra-tidal profile of M 92 as follows: at radii just beyond the fitted King profile tidal radius, the profile resembles a halo of stars -most likely still tied up to the cluster or in the act of being stripped away. As the latter process is not instantaneous, these stars will still be orbiting near the cluster for some time. We cannot say whether this is due to heating caused by tidal shocks, or to ordinary evaporation: a deep CCD photometry to study the mass function of extra-tidal stars would give some indications on this phenomenon. At larger radii, the 1  $\sigma$  "isophote" shows a barely apparent elongation of the profile in the direction SW to NE, with some possible features extending approximately towards S and E. Although the significance is only at 1  $\sigma$  level, these structures are visible and might be made up by stars escaping the cluster and forming a stream along the orbit. As pointed out in Meylan & Heggie (1997), stars escape from the cluster from the Lagrangian points situated on the vector connecting the cluster with the center of the Galaxy, thus forming a two-sided lobe, which is then twisted by the Coriolis force. A clarifying picture of this effect is given in Fig. 3 of Johnston (1998).

### 4. Summary and conclusions

We investigated the presence and significance of a tidal extension of the brightness profile of M 92. The main results of our study are:

- 1. The presence of an extra-tidal profile extending out to  $\sim 0.5^{\circ}$  from the cluster center, at a significance level of  $3 \sigma$  out to  $r \sim 2000$  ". We found no strong evidence for preferential direction of elongation of the profile. This may imply that we are detecting the extra-tidal halo of evaporating stars, which will later form a tidal stream. Moreover, the tidal tail might be compressed along the line of sight-see, for instance, Fig. 18 of G95. In fact, G95 point out that tidal tails extend over enormous distances ahead and behind the cluster orbit, and the volume density is subject to the open-orbit analogous of Kepler's third law: near apogalacticon, stars in the tidal tail undergo differential slowing-down, so that the tail converges upon the cluster. Actually, most models (e.g., Murali & Dubinski 1999) predict that the extra-tidal material should continue to follow the cluster orbit and thus take the shape of an elongated tail, or a stream. The stream has been already revealed in dwarf spheroidal galaxies of the local group (Mateo et al. 1998), but whether the stream can also be visible in significantly smaller objects like globular clusters is currently a moot point.
- 2. By constructing the surface density map and performing a Gaussian smoothing, the low-frequency features are enhanced over the background. We find some marginal evidence for a possible elongation in the extra-tidal extention based on a visual inspection of this map. This elongation may be aligned in a direction perdendicular to the Galactic center, although we already know that the significance of this result is low; additional observations will be required to settle the issue. A similar displacement is described in Fig. 3 of Johnston (1998).

Finally, we want to stress the power of the DPOSS material in conducting this kind of programs, either by using the standard output catalogs, as they come out from the processing pipeline, or the specific re-analysis of the digitized plate scans. In the future we will extend this study to most of the globular clusters present on the DPOSS plates.

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